FUNDY TIDAL POWER

STAGE 1

REPORT OF TIDAL POWER CORPORATION

DECEMBER, 1985

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APPENDICES

(Included)

1. Scope of the Work
   (excerpts from the project brief)

(Separate documents)

2. Fundy Tidal Power Stage 1
   Report of Alcan Aluminium Limited

3. Fundy Tidal Power Stage 1
   Report of Tidal Power Consultants to Alcan

   Volume 1 - main report
   Volume 2 - appendices

4. Materials prepared for Alcan Aluminium Limited
   for the Bay of Fundy Tidal Power Study
   First Boston Corporation

   2 volumes

5. An update on the effects of tidal power development on the tidal regime of the Bay of Fundy and the Gulf of Maine
   Discovery Consultants Limited

INTRODUCTION

Investigations undertaken at various times over the last two decades have led to a good general understanding of the potential for tidal power development in the Bay of Fundy. The most appropriate sites have been identified. Technically sound designs and construction methods have been defined. There is at least a qualitative understanding of environmental implications. Development has been predicted to yield net economic benefits (1),(2).

This was the state of affairs portrayed in Tidal Power Corporation's report "Fundy Tidal Power: Update '82". The progress made had been encouraging but fell far short of providing the basis for undertaking to build a large tidal power plant. Before such a project could be committed for construction, much more preliminary work was needed. The requirements included, among other things, detailed designs and cost estimates, environmental assessment, rights-of-way for transmission to market, and conditional agreements relating to financing and sale of output.

These activities, sometimes referred to as a pre-commitment program, were estimated to cost between $50 and $100 million. Such large expenditures would have been justifiable only if prospects for carrying a project through to completion appeared favourable.

In the latter part of 1982 an expression of private sector interest was received from Alcan Aluminium Limited (Alcan). This resulted in a staged program leading to development. The first stage was intended to determine whether conditions were sufficiently favourable to warrant undertaking the pre-commitment activities which would comprise the second part of the program.

As a result of discussions between all concerned, including the Governments of Canada and Nova Scotia, it was decided to undertake the first part of the program, which was formally designated as "Stage 1".

The agreed work has now been completed. It is well documented by the reports of Alcan and other participants which are incorporated by reference and listed as appendices. This report has been prepared to present an overview, based on Tidal Power Corporation's review of the activities, results and conclusions.

STUDY APPROACH AND CONTENT

The Stage 1 program was designed to determine conditions of feasibility for a selected tidal power development and to assess whether such requirements could be met. It comprised three lines of inquiry: technical, financial and marketing.

Technical.

The technical content was intended partly to fill some gaps in earlier work. The Update had identified a new approach to design and construction scheduling, but had applied it only to site B9 in Minas Basin, where it had been found cost-effective. (See Figure 1 for site locations.) In the present work the same approach was applied to site A8 in Cumberland Basin.

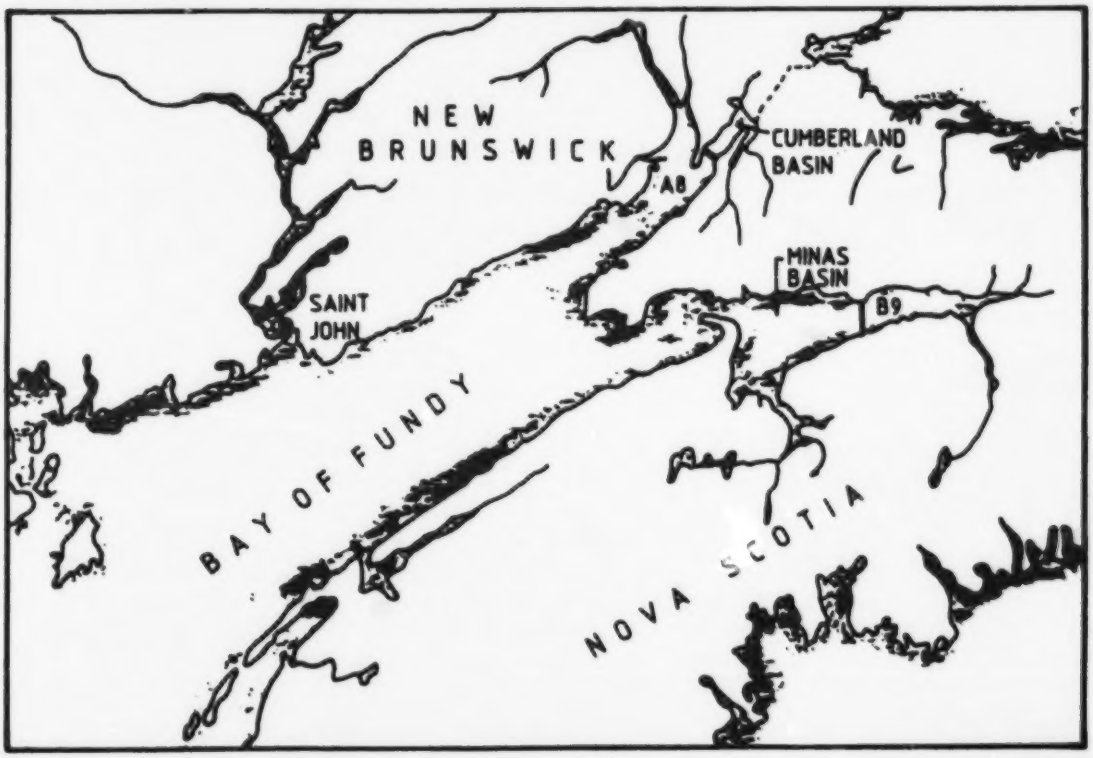

FIGURE 1: LOCATION OF TIDAL PLANT SITES

A few other possibilities for reducing total or per-unit capital costs had been recognized, but had never been examined for feasibility or cost-effectiveness in relation to the Fundy sites. They included variable-speed turbines, straight-flow turbines, steel caissons and refinements in caisson design. It was deemed appropriate to investigate these possibilities.

Capital costs for B9 had been estimated directly from designs at 1981 prices, while costs for A8 had last been estimated directly from Tidal Power Review Board designs at 1976 prices. The work program therefore provided for new estimates of A8 costs based on the designs emanating from the study, and for the updating of B9 costs by inference from A8 data.

The criterion of design optimization used in previous studies and retained in the present case is least cost per unit of output. Because changes in design and in the relative cost of various components lead to changes in installed capacity, operating heads and turbine parameters, it was therefore necessary to provide for recalculation of plant outputs as an integral part of the design procedure. Results were obtained directly for A8 and by inference for B9.

The intent of these procedures was to establish reliable estimates of direct capital cost and output for both sites, based on technically feasible designs of optimal economy.

Site selection.

Based on the results of technical studies, and on all other relevant information, the work program required a specific site to be chosen, both as the focal point for the remainder of the studies and as the candidate for a first development.

Financial.

The annual costs of owning and operating a tidal generating station consist mainly of debt charges. Operating and maintenance costs are minimal and there are of course no fuel costs. Thus the cost of product is determined almost completely by two factors--the cost of plant and the cost of money. Financial studies were intended not only to define the latter, but also to identify the peripheral conditions of financial feasibility for the selected project.

The approach to be taken was not defined in the work program, but rather left for decision in the light of preliminary results.

Marketing.

In previous studies, no direct assessment of the marketability of tidal energy had been made. The direct economic benefits had been computed through simulation of utility system operations and the results had been compared to the direct economic costs. As in any attempt to forecast future events or conditions, a number of assumptions were necessarily made, and in this sense the results were subjective.

The Stage 1 approach involved ascertaining the interest of prospective purchasers. It should be recognized that the results of this procedure are no less subjective, but they are influenced by the judgment of the buyer, which, under the circumstances, is likely to be more relevant than the judgment of the seller.

Project brief.

The scope of the Stage 1 work was agreed by all concerned and formally defined in a project brief, which provided the basis for agreements between the parties. The relevant portions of the brief are reproduced in Appendix 1 attached.

ORGANIZATION

The work was funded through the Canada-Nova Scotia Agreement on Oil Substitution and Conservation and performed under a contract between the Province of Nova Scotia and Tidal Power Corporation. Alcan undertook to manage and co-ordinate the work.

A study team was formed to organize and administer the studies, and to conduct specialized portions thereof. It consisted of:

M. D. Lester, Alcan	- Study Manager
H. Roth, Alcan	- Financial Liaison
R. H. Lalande, Consultant	- Commercial Liaison
J. T. Madill, Consultant	- Technical Liaison

The various tasks were performed as follows:

Technical studies:

Tidal Power Consultants Ltd., Montreal, assisted by:

Wilson Energy Associates Ltd., Stockport, England
(energy calculations)

Dominion Bridge-Sulzer Inc., Lachine, Quebec
(turbine costs and performance)

Brown Boveri Canada Inc., Montreal, Quebec
(generators and HVDC equipment)

Both Belle Robb Ltd., Montreal, Quebec
(construction methods, schedules and costs)

Financial studies:

The Study Team

First Boston Corporation, New York
(financial analysis)

Marketing studies:

The Study Team

Tidal regime modelling:

Discovery Consultants Ltd., Wolfville, Nova Scotia

TECHNICAL STUDIES

The technical studies are fully documented in the consultant's report (Appendix 3). The work and results are briefly summarized in this section.

Methodology.

The technical studies focussed on development of site A8 in Cumberland Basin as a single basin single effect tidal generating station with barrage extending from Peck's Point to Boss Point.

Production studies were carried out using a single tide optimization model capable of reflecting cavitation limitations and other turbine parameters, basin and sea water levels.

Four turbine configurations were considered, all with fixed propellors and wicket gate regulation. The variants were bulb or straight flow, fixed or variable speed.

Turbine caissons were designed for each type of turbine. Sluices and cribs were based on previous designs.

The approach to barrage construction previously developed for site B9 was applied. This involves placing sluice and turbine caissons in deep water, placing temporary sluice caissons or blind caissons in shallower water and constructing dykes in water too shallow for caisson flotation. Horizontal closure would be effected by placing blind caissons, with currents minimized by maximum water passage through turbine, permanent and temporary sluice caissons.

Four barrage profiles were considered, permitting progressively larger numbers of active elements (sluice and turbine caissons) to be set, at the cost of progressively greater underwater rock excavation to secure the necessary depth.

For each profile, the number of turbines was varied through an appropriate range with the remainder of the available space in active elements being utilized by sluices. The optimum was selected on the basis of output versus cost. Finally the best of the four optimized profiles was selected.

Delivery of output to Ludlow, Massachusetts, was assumed, and transmission line characteristics were determined on the basis of capital cost and energy losses.

Cost estimates were prepared, both for purposes of design and to determine total project capital requirements. The estimates were based on constant dollars of January 1, 1984 purchasing power inclusive of appropriate allowances for contractors' profits, owner's expense and contingencies. Interest during construction was omitted. Construction schedules were prepared, and construction cash flows were computed therefrom.

Results.

The new approach to design and construction was found to result in lower unit costs than the older Tidal Power Review Board design.

Variable speed turbogenerators were found to be technically feasible and the Straflo turbine was recommended, subject to continued successful experience with the machine of this type now operating at the Annapolis Tidal Generating Station. To minimize powerhouse electrical costs, groups of turbines would operate in internal synchronism, but not necessarily at the frequency of electrical systems. Output of each group would be transformed and rectified for DC transmission.

Although steel was considered as an option for caisson design, it was rejected in favour of concrete. The caissons designed for Straflo units would be set on a prepared mattress at an elevation 1 m higher than the corresponding bulb caissons. They are also slightly shorter from intake to tailrace.

Principal characteristics of the new design are summarized in Table 1.

TABLE 1

SITE A8 DESIGN FEATURES

Barrage length (m)	2,560
Dyke length (m)	1,340
Number of powerhouse caissons	21
Number of deep sluice caissons	6
Number of shallow sluice caissons	4
Number of turbines	42
Diameter (m)	7.5
Rating (MW)	34
Installed capacity (MW)	1,428
Rated head (m)	9.1
Speed range, RPM	(35-73)
Transmission line, ±450 KV, DC, km	860
Plant cost (millions of $C, Jan. 1984)	1,892
Transmission line cost (millions of $C, Jan. 1984)	668
Total cost (millions of $C, Jan. 1984)	2,560
Annual output, net of transmission losses, GWh	3,307

Estimated construction cash flows and energy produced during construction are shown in Table 2. Energy production would start following closure with the turbines installed at that time. The production rate would increase as additional turbines were installed. The costs cited in Tables 1 and 2 are gross; they do not include any deduction or credit for the value of energy produced during construction.

Relatively few changes resulted from the updating of the B9 design, because it had previously been optimized under the current design philosophy. Variable speed turbines were specified as for A8 and installed capacity and output were changed accordingly. The cost estimate was increased due to the lower purchasing power of 1984 as compared to 1981 dollars. Main features of the design are summarized in Table 3.

TABLE 2

Schedule of capital expenditures and energy received

TIME *		Capital Expenditures Can. $ x 10^6 Jan'84 value	Energy received by NEPOOL at Ludlow, Mass.	
YEAR NO.	MONTH NO.		GWh/month	GWh/year
1	1 -11	19		
2	12 -23	166		
3	24 -35	245		
4	36 -47	473		
5	48 -59	652	-	
6	60 -71	551		
7	72 -83	357	27.6**	28
8	84		55.1	
	85		82.7	
	86		110.2	
	87		137.8	
	88		165.4	
	89		192.9	
	90		220.5	
	91		248.0	
	92		275.6	
	93		275.6	
	94		275.6	
	95		275.6	
	84 -95	97	-	2315
9	96-107	-	275.6	3307
10	108-119	-	275.6	3307
			etc	etc
Capital cost		$2,560		

* The receipt of notice to proceed with detailed design, i.e. after completion of feasibility study, is point zero on the time scale.

** This energy generated during month 83.

TABLE 3

SITE B9 DESIGN FEATURES

Barrage length (m)	8,000
Dyke length (m)	1,800
Number of powerhouse caissons	62
Number of deep sluice caissons	11
Number of shallow sluice caissons	35
Number of turbines	128
Diameter (m)	7.5
Rating (MW)	41.7
Installed capacity (MW)	5,338
Transmission line, ±450 KV, DC, km	980
Plant cost (millions of $C, Jan. 1984)	5,800
Transmission line cost (millions of $C, Jan. 1984)	1,200
Total cost (millions of $C, Jan. 1984)	7,000
Annual output, net of transmission losses, GWh	13,780

Estimated construction cash flows and energy produced during construction are shown in Table 4. As in the case of A8, the cited costs are gross, without any credit for the value of such energy.

TABLE 4

Schedule of capital expenditures and energy received

TIME *		Capital Expenditures, $Can. \$ \times 10^6$ Jan.'84 value	Energy received by NEPOOL at Ludlow, Mass.	
YEAR NO.	MONTH NO.		GWh/month	GWh/year
1	1 -12	25.4	-	-
2	13 -24	177.8	-	-
3	25 -36	298.4	-	-
4	37 -48	692.1	-	-
5	49 -60	800.1	-	-
6	61 -72	927.1	-	-
7	73 -84	997.0	-	-
8	85 -96	1022.3	-	-
9	97	↓	77	↓
	98		154	
	99		232	
	100		309	
	101		386	
	102		463	
	103		541	
	104		618	
	105		695	
	106		714	
	107		733	
	108		753	
	97 -108	743	-	5675
10	109	↓	772	↓
	110		791	
	111		811	
	112		830	
	113		849	
	114		869	
	115		888	
	116		907	
	117		927	
	118		946	
	119		965	
	120		984	
	109 -120	650.0	-	10,539
11	121	↓	1002	↓
	122		1020	
	123		1038	
	124		1057	
	125		1075	
	126		1093	
	127		1112	
	128		1130	
	129		1148	
	130		1148	
	131		1148	
	132		1148	
	121 -132	469.9	-	13,119
12	133 -144	196.9	1148	13,780
13	145 -156	-	1148	13,780

Capital cost $7,000.

* The zero point on the time scale is the receipt of notice to proceed with detailed design, i.e. after completion of feasibility study.

CHOICE OF TARGET SITE FOR DEVELOPMENT

Results of the technical studies indicated that energy could be produced at lower unit cost from B9 than from A8. The direct capital investment in A8 per kilowatt-hour of annual output is 77¢, while the corresponding figure for B9 is 51¢. This rough basis of comparison does not reflect differences in construction time and energy produced during construction. If these factors are included and energy during construction is credited at cost, unit costs of B9 output range between about 62 and 73 percent of A8 costs depending on interest and inflation rates.

Other relevant factors favoured A8:

1. While of substantial size, it is much smaller than B9 and, on that basis alone, a more prudent choice for first development.

2. Because of its smaller capital requirements, financing and other associated matters would be less difficult to arrange.

3. Increased tidal amplitudes along the New England coast were predicted to be about five times larger for B9 than for A8. There had been expressions of concern in the United States about the effects of constructing B9. Whether or not the concerns were justified, it was apparent that B9 development was likely to incur opposition.

4. The A8 site borders both Nova Scotia and New Brunswick. An A8 project was considered likely to attract broader support because of its interprovincial character.

For these reasons, A8 was judged to be the more practical project for first development and was therefore selected as the target site.

ENVIRONMENTAL ASPECTS

As originally defined, the Stage 1 program made no provision for environmental investigations, which were envisaged to be included in the pre-commitment stage. However, it is appropriate to consider environmental impacts in the context of project feasibility, and present perceptions are summarized here.

Due to research carried out over the past eight years by various agencies and co-ordinated by the Fundy Environmental Studies Committee, there is a fairly good understanding of the Fundy ecosystem and of the potential effects of tidal power development. There would be many effects, both good and bad; but from the viewpoint of an entrepreneur, very few are potentially serious enough to bar progress. These include the effects of larger tides in the lower Fundy and Gulf of Maine, potential effects on the Gulf of Maine fishery, and potential effects on fish due to tidal plant operation.

Tidal regime.

The original predictions of tidal effects had been made by means of a hydrodynamic numerical model developed by Greenberg (3). The predicted increases in tidal amplitude at Boston were about 15 cm for B9 and about 3 cm for A8. These predictions were made for the M2 (lunar semi-diurnal, or mean) tide and thus were not necessarily valid for actual tides, which contain many other constituents in addition to the M2.

Furthermore, tidal plant designs had changed since the original predictions had been made, providing for higher turbine and sluice capacities. These changes were capable of exerting some effect on the tides.

In view of expressed U. S. concerns about higher tides in the Gulf of Maine (4) it was deemed expedient to obtain new and if possible more accurate predictions. This work was duly authorized and completed. A full account of the methodology and conclusions is contained in the consultant's report (Appendix 5). The findings may be summarized as follows:

1. The extra turbine and sluice capacity of present designs reduces the amount of perturbation. For mean tides, the increase in amplitude at Boston would be about 12 cm for B9 and 2 cm for A8.

2. The increases are not uniform for all tides but vary upward or downward by about 30% of the mean.

3. The extent of the perturbation is noticeably affected by the permeability of the barrage and can be dramatically reduced by leaving sluice gates open throughout the tidal cycle. In this case the perturbation due to B9 drops to about 3 cm and that due to A8 to virtually zero.

4. The effect of opening sluice gates is fully established within 12 to 18 hours depending on the phase of the tide when the gates are opened.

5. Changes in phase of flow through the barrage do not noticeably affect the amount of tidal perturbation.

These findings have implications of importance to the development of A8 and possible successor sites.

In the present context, the environmental reason for selection of A8 as the target site is confirmed and enhanced. The far-field effects of this site on the tidal regime would be so slight that it might be reasonable to ignore U. S. impacts. In this case environmental regulation and control would be simplified. Protracted delays would be avoided.

In the context of successor sites, it is apparent that simple means exist to minimize far-field effects at times of storm surge, providing only that 12 to 18 hour advance warning is available. It is further apparent that regime effects can be minimized by selection of installed capacity near the top of the economic range rather than at the optimum or near the bottom.

Effect on the Gulf of Maine fishery.

Increased tidal amplitudes in the Bay of Fundy and Gulf of Maine would affect water temperatures, larval distribution, the degree of mixing and the supply of nutrients. While the changes induced by constructing a tidal plant would be small, fish stocks would be sensitive to even small changes.

A preliminary indication of the effects to be expected is afforded by a recently conducted study (5). Tidal amplitudes are regularly altered over long periods by the 18.6-year nodal cycle, and the work consisted of examining fish catch records for a correlation with that cycle. Catches of cold water species were found to vary positively with higher tides, while for one warm water species the correlation was negative. Results appear to indicate that construction of tidal plants would not produce a negative effect on this important fishery and might have a positive effect.

For the small perturbations caused by A8, the effects would be negligible and there appears to be no cause for concern.

Effects at the barrage.

A tidal barrage would have two potential direct impacts on fish: an impediment to the passage of anadromous fish on spawning runs and the imposition of extra mortality on fish passing through the turbine.

Delay and disorientation of anadromous fish would probably not be serious and could be mitigated by appropriate design. Turbine mortality is potentially more serious. Fish likely to be passed through the turbines include post-spawned adult and juvenile anadromous fish, as well as pelagic species. Of the latter, shad give the greatest cause for concern because it is believed that every fish of that species spends some time in both Minas and Cumberland Basins during its life cycle. While there, it tends to move in and out with the tides and would be exposed to multiple turbine passages.

Experience at the Annapolis Tidal Generating Station has indicated that mortality imposed by the turbine on shad and perhaps some other species is higher than originally predicted (6). The Annapolis turbine is quite similar to those which would be used in a large tidal power scheme. In consequence, the Annapolis experience is considered indicative.

It is concluded that effective means for the mitigation of fish mortality would have to be provided as a condition of feasibility for any large-scale tidal power generating station. This conclusion applies with equal force to A8 and B9.

Further investigation at Annapolis is planned, both to determine the best methods of mitigation and to test their effectiveness.

FINANCIAL

In view of the uncertainties surrounding future interest and inflation rates, and in order to reduce the number of variables to be considered, financial analysis was based on real interest and real rates of return. Variables examined were energy prices, real interest rates, debt/equity ratio, income tax and exchange rates. Tidal plant construction costs, operating costs and output, determined by the technical studies, provided basic data for a financial model in which permutations of the variables were tested.

The effect of interest rate in terms of levelized U. S. currency prices required to amortize the investment in 25 years is indicated by the following figures:

Debt %	Equity %	Interest Rate %	Tax %	Approximate Price ¢/KWh (U. S.)
100	0	4	0	3.8
100	0	6	0	4.3
100	0	8	0	5.8

Equity participation would increase prices by an amount dependent on the required return on equity, and taxation would result in further increases. The prices indicated are for unretimed tidal energy, generally speaking only useful for the displacement of thermal fuels. The figures indicate that even under these least cost assumptions, energy from A8 would be competitive only with real interest rates in the 4% range.

Two excerpts from the financial consultant's report (Appendix 4) put the situation in proper perspective:

> In a capital intensive project, the primary concern is the financing cost. Capital markets in recent years have exacted a real interest rate substantially above historical levels. The impact of this high real interest rate environment on the Bay of Fundy Project is unfavourable. It does not permit the low long-term operating costs of the Project to compensate fully for the high capital cost and long construction period. The present high real interest rate environment distorts the perception of the long-term value of the Project. If we were to return to a more normal (by historical standards) real interest rate environment, the appeal of the Project would be substantially enhanced.

> . . . if real interest rates drop back to historical levels of 3-4%, the Project could become feasible. The problem now is whether to commit for three years of engineering studies at an estimated cost of $100 million in hopes of a change in perceptions of inflationary trends and the relationship between inflation rates and nominal interest rates.

The study team recognized that this difficulty could be resolved if project financing could be arranged at an index-linked interest rate consisting of a real component of approximately 4 percent plus an inflation component equal to the current year's inflation rate. It was ascertained that financing of this type would, with a high probability, be available for the A8 project.

The implication of index-linked financing is that project revenues would have to vary in response to changes in the total interest rate. The uncertainties inherent in inflation rates would thus be passed on to the consumer. This, in the event that fixed-rate financing at traditional levels of real interest was not available, would be the fundamental condition of financial feasibility.

Moreover, it is a reasonable condition. The cost of energy from most alternative sources would also be subject to inflationary increases, so its acceptance would not expose the customer to additional risk.

MARKETING

The present studies were designed to evaluate the marketability of tidal energy by direct approach to appropriate utilities. Because the New England Power Pool (NEPOOL) is a large system and because it is projected to remain partially dependent on oil-fired generation beyond present planning horizons, it was considered the most likely prospect.

Through discussions it was determined that NEPOOL would not be interested in purchasing unretimed tidal energy. NEPOOL projected that the energy could not be retimed through its energy banking agreement with Quebec because the interconnection would be loaded to capacity during the daily peak period. Direct absorption was deemed unattractive because at periods of low load no oil-fired generation would be available for displacement and technical problems were envisaged due to the rate of change of tidal power output.

On the other hand, NEPOOL expressed interest in obtaining additional firm capacity from retimed tidal energy and other Maritime sources. Difficulties were anticipated in providing the extra transmission capacity needed to effect delivery at southern New England load centres.

Tidal energy may be retimed in several ways, of which the most economically attractive is the co-ordinated operation of river hydro plants. This requires that the river hydro has water storage equivalent to about one cycle of tidal energy, that it has, or is incremented by, enough spare generating capacity to supply the retimed tidal output, and that its normal output equals or exceeds the peak tidal output. For A8, this would mean storage for about 6,000 MWh, spare capacity of about 750 MW and normal output of 1,320 MW. Retiming by this method has the advantage that it entails no significant loss of energy. The costs are the costs of spare capacity.

Retiming may also be accomplished by compressed air energy storage, which requires the use of gas turbines to recover the energy and thereby incurs limited exposure to inflation and fuel price escalation.

Pumped storage is a third method of retiming. This requires high and low storage ponds plus a pump-turbine installation. In-and-out energy losses would approach 30% of the energy stored, or about 15% of tidal plant output.

Because of its evident superiority, retiming by means of existing hydro is the preferred option. Hydro installations of the necessary size and character do not exist in the Maritimes and Hydro Quebec was therefore asked whether it would be willing to undertake the retiming of A8 output. No answer has yet been received. This is understandable because matters of policy are involved which could perhaps only be resolved within the framework of political policy. At that time, Quebec was in a state of political uncertainty. The study was therefore terminated under pressure of contractual time limits without resolution of the retiming question and, in consequence, without pursuing the matter further with NEPOOL.

Hydro Quebec might or might not have more enthusiasm for retiming tidal energy for the Maritimes than for the New England market. If retimed, one of the main constraints against absorption of output by Maritime electric systems would be greatly reduced. If retimed to be available for 12 hours per day coinciding with the daily peak load, A8 would provide upward of 750 MW of firm capacity at 50% annual capacity factor. This would be appropriate for displacing cyclical thermal generation on the load curve.

The question of whether such energy would be attractive to Maritime utilities was not resolved. Apart from comparative costs, there are at least two complicating factors; a single increment of 750 MW is rather larger than the present economic optimum, and to the extent that tidal power might be an alternative to nuclear or coal, social benefits external to utility operations might well be involved.

ECONOMIC APPRAISAL

Previous studies had determined that the greatest economic benefit would be realized from tidal energy through absorption of the unretimed cyclical output by utility systems. This conclusion rested in part on the assumption that fuel prices would increase in real terms; an assumption which tended to render capital investment for the upgrading of tidal energy less attractive. It was supported by the finding that absorption of unretimed tidal energy was technically feasible providing such energy constituted only a small fraction of system energy requirements.

The response received from NEPOOL in the course of the marketing studies appears at first glance to refute these ideas, but that appearance may be superficial. What was being tested was the saleability of tidal energy, and factors having little or no relation to utility system economics were clearly involved; among them a regulatory climate which inhibits investment in utility plant.

Due to the inconclusive nature of the market investigations, and in the belief that economic factors are likely to carry decisive weight in the long run, Tidal Power Corporation deemed it appropriate to make some comparisons of cost between tidal energy from A8 and sources with which it would have to compete in New England and Maritime markets.

The comparisons were made under the assumption that oil and coal costs would not escalate in real terms; i.e. their prices would rise at the rate of general inflation. Present-day utility estimates of capital costs for oil, coal and nuclear generating stations were used. No assumptions were made with respect to interest and inflation rates; costs were calculated for a range of both rates. It was assumed that Hydro Quebec would retime tidal energy at cost plus fair return.

In the Maritimes, retimed A8 energy at 50% capacity factor would have a first-year cost higher than the equivalent energy from coal-fired plants at all levels of interest and inflation. On the basis of 30-year levelized costs A8 energy would also be more expensive than coal-fired energy by a margin of 28 to 45%, depending on inflation rates. Tidal would have a first-year cost lower than oil-fired generation at low rates of inflation and a levelized cost lower than oil-fired generation at all realistic levels of inflation.

No direct comparisons were made for nuclear energy because it would not be appropriate to use such a plant to supply the cyclical part of the daily load curve.

In the northeastern United States, the 30-year levelized cost of retimed A8 energy would be competitive with coal-fired thermal at 50% capacity factor. Tidal would be cheaper than oil-fired generation.

These results suggest that retimed tidal energy would be competitive in the New England market under all conditions. In the Maritimes, tidal energy could be competitive only if:

(a) Coal prices should increase faster than the general rate of inflation; or

(b) Environmental protection requirements should add materially to capital and operating costs of coal-fired thermal plants; or

(c) The amount of oil-fired thermal generation in the Maritime system should substantially exceed present projections.

It is further apparent that under the assumption that fuel prices will not be subject to differential escalation, energy from A8 would be too expensive to compete in its unretimed form as displacement energy.

DISCUSSION AND CONCLUSIONS

The technical studies resulted in several design improvements, principally the use of variable speed turbogenerators, but the impact on plant costs was relatively minor. Alcan noted that the cost per unit of installed capacity for these sites is in the lower part of the range covered by contemporary hydro projects. These circumstances suggest that tidal technology has reached a mature phase.

Conclusion 1.

It is concluded that further technical work aimed at reducing development costs should be accorded a relatively low priority.

The studies did not give a clear indication that tidal power from site A8 could be marketed. Conversely, there was no clear indication that output could not be marketed. The answer would depend at least to a certain extent on finding means to retime the output, converting it from intermittent pulses into firm capacity and energy.

Transmission access is a necessary condition for sale of tidal energy in New England. Present capacity is now at times insufficient to deliver exports from New Brunswick to southern New England. Development of additional capacity for Maritime exports is viewed by some observers as impossible under present circumstances and likely to be possible in future only with benefit of broad political and regulatory support. Only a significant block of power and energy would be likely to attract such support.

Conclusion 2.

It is not deemed appropriate to launch the Stage 2 (pre-commitment) program until some further resolution of marketing, retiming and transmission questions is achieved.

Results of the marketing studies must be considered in the light of present circumstances. One such circumstance is the character of regulatory policy in some New England states, which tends to inhibit investment in new capacity to meet future load growth. Another is the declining real cost of fuel. Retention of present oil-fired generating capacity is thus on the one hand made necessary and on the other made tolerable.

A tidal plant could not be in service earlier than the mid-1990's, and any judgment as to its usefulness or the markets open to it cannot be made conclusively on the basis of present circumstances; they may change greatly in a decade. Indeed, another upswing in oil prices is widely forecast to occur before the turn of the century. Whether it does or not, retimed output of A8 is likely to be marketable. It is less certain, but possible, that unretimed output from A8 would be marketable as displacement energy.

Conclusion 3.

If means of retiming A8 at reasonable cost can be established, Stage 2 studies should be undertaken promptly.

Because of its long construction time, capital cost of a tidal plant is adversely affected by inflation and concommitant high interest rates during the construction period. By contrast, after the plant is completed and in operation, it is relatively immune to such factors and they merely serve to make tidal energy more attractive. Other things being equal, now would be the best time to undertake a tidal project. After oil prices surge again might be too late.

Conclusion 4.

High priority should be given to establishing feasible conditions for development of A8. In particular:

(1) A concerted interprovincial effort should be made to respond positively to NEPOOL's expressed interest in a substantial power export package from the Maritimes;

(2) The ability of Maritime utilities to absorb or partially retime A8 output should be further investigated; and

(3) The feasibility of constructing a large retiming facility in the Maritime Provinces should be investigated.

ACKNOWLEDGMENTS

All the study tasks were well performed by the various groups and agencies responsible for the work. The study also benefited greatly from the co-operation of New England Power Pool, New Brunswick Electric Power Commission, and Nova Scotia Power Corporation.

Alcan had no interest in tidal power as a source of electricity for its own operations, but became involved because of a conviction that development of the Fundy tidal resource could be beneficial to the public interest. To the preparatory work and conduct of the studies Alcan devoted its corporate and personnel resources without asking for or receiving compensation of any sort.

Murray D. Lester, at that time Alcan's Vice-President, Energy Resources, participated in the preparatory phases and managed the studies with energy, enthusiasm and ingenuity.

Alcan's involvement, although it did not trigger an immediate start of the pre-commitment phase, has contributed greatly in providing a firm basis for further progress toward development of the Fundy tidal resource; a contribution which Tidal Power Corporation acknowledges with gratitude.

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APPENDIX 1

EXCERPTS FROM THE PROJECT BRIEF

2.0 Stage I Objectives

The objectives of the Stage I program include:

2.1 Determination of optimum design, related energy output and current estimate of capital cost for selected sites.

2.2 Selection of a specific project as a development target.

2.3 Calculation of the generating costs, transmission costs and the amounts and timing of the revenues required to attain financial viability for the selected project.

2.4 Determination of the commercial viability of tidal energy output in the light of the calculated financial criteria.

3.0 Work Description

3.1 Plant design, capital costs and output.

The work will deal primarily with a plant of about 1,200 MW installed capacity at site A8 in Cumberland Basin.

Using as a base case the design recommended in the 1977 reassessment, the effect on capital costs of three major variations will be investigated. The variations will consist of:

(a) Improved construction techniques;

(b) HVDC transmission to market; and

(c) Use of variable speed turbogenerators.

In addition, the technical desirability and cost effectiveness of other variations will be investigated, including but not necessarily limited to:

(a) Bulb versus Straflo turbine;

(b) Prefabricated steel caissons versus concrete caissons;

(c) Perforated walls on the ocean side of caissons for wave energy dissipation;

(d) More efficient shape of powerhouse water passages; and

(e) Deviations of barrage alignment.

For site B9 in Minas Basin, costs of the Update '82 design will be revised by the application of unit costs determined in the course of the A8 work described above. In addition, if significant improvements are found to result from the design variations examined in relation to A8, the effect of applying such variations to B9 will be estimated by inference only. B9 designs will not be specifically revised to incorporate such variations.

This work will be performed by Tidal Power Consultants Limited under contract.

3.2 Determination of revenue requirements.

Based on the results of 3.1 above, a specific development project will be selected.

Various financing structures will be examined in order to establish realistic estimates of the revenue requirements. With this as background, commercial viability will be tested for several organizational and marketing models.

3.3 Determination of marketability.

The main provisions of appropriate agreements covering the sale of tidal energy will be developed to conform with the determined costs, the selected financial organization and other pertinent factors.

The marketability of tidal energy under such agreements will be tested by direct approach to appropriate utilities. Consideration will be given to the possibility of retiming the tidal energy by means of the proposed interconnection between the New England system and Hydro Quebec.

It is the intention that work defined in 3.2 and 3.3 will be performed directly by Alcan and/or by agencies selected by Alcan.

3.4 Reports.

Reports will be prepared providing adequate documentation of each step of the work and the results thereof.

4.0 Management and Control

All aspects of Stage I work will be performed under the direct management and control of Alcan Aluminium Limited. Progress and results will be forwarded to and reviewed by Tidal Power Corporation.

5.0 Availability of Documents

Upon completion of the work, copies of all working papers, drawings, reports and other documents shall be kept for reference and shall be available on demand to Energy, Mines and Resources Canada and/or Tidal Power Corporation.